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THERMOLUMINESCENCE PROPERTIES OF LITHIUM BORATE GLASS SUBJECTED TO ^{60}CO GAMMA RAY

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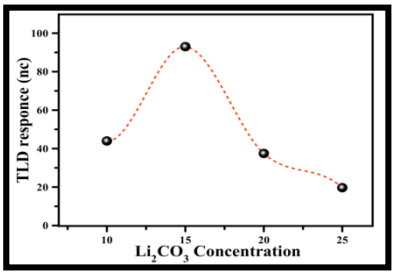
Graphical abstract



Abstract

Glass samples with composition of xLi_2CO_3-(100-x) H_3BO_3, with 10 ≤x ≤ 25 were prepared by melt-quenching technique. The amorphous structure, sample morphology and thermoluminescence (TL) properties of the prepared samples were determined using powder X-ray diffraction (XRD) spectrometer, field emission scanning electron microscope (FE-SEM) and TLD reader, respectively. The samples were irradiated to Co-60 gamma source. The FE-SEM results show that the morphology of the prepared samples was in homogenous and transmitted surface. Furthermore the amorphous phase was confirmed by XRDanalysis. It was also found that the composition of Li_2CO_3 and H_3CO_3 affected the TL response and the highest TL response was observed for the sample with composition 15 mol % Li_2BO_3 and 85 mol % of H_3CO_3after being irradiated to 10 Gy gamma ray. The sensitivity of this sample was of about 138.306 nC g^{-1} Gy^{-1}.

Keywords: Lithium borate, Co-60 gamma, thermoluminescence, X-ray diffraction, FESEM

Abstrak

Sampel kaca dengan komposisi xLi_2CO_3-(100-x) H_3BO_3, dengan 10 ≤x ≤ 25 telah disediakan dengan teknik penglindapan lebur. Struktur amorfos, morfologi sampel dan sifat-sifat luminesensterma (TL) bagi sampel yang disediakan masing-masing ditentukan menggunakan spectrometer belauan sinar-X (XRD), mikroskopimbasan pancaran medan electron (FE-SEM) dan pembaca desimeter luminesensterma (TLD). Sampel disinarkan kepada punca gama Co-60. Hasil FE-SM menunjukkan morfologi sampel yang disediakan merupakan permukaan homogeny dan terpancar. Selanjutnya, fasa amorfos sampel disahkan menggunakan analisis XRD. Kajian ini juga mendapati komposisi Li_2CO_3 dan H_3CO_3 dalam sampel member kesan kepada sambutan TL dan sambutan TL tertinggi diperhatikan bagi sampel dengan komposisi 15 mol % Li_2BO_3 dan 85 mol % H_3CO_3 selepas disinarkan pada dos 10 Gy sinargama. Kepekaan sampel tersebut adalah kira-kira138.306 nC g^{-1} Gy^{-1}.

Kata kunci: Litiumborat, gammaCo-60, luminesensterma, belauanX-ray, FESEM

1.0 INTRODUCTION

There are several natural and synthetic borate that used in many industry applications, due to their high impurity in processing plants and are further treated with more qualified finishing products such as boric acid, anhydrous boric, anhydrous borax, borax pentahydrate, borax decorate, borax decahydrate, and sodium perborate) in recrystallizer units. However, the variability of borate crystal chemistry [1, 2], which allowed the researchers to synthesize different types of the borate that variations in their structures to be used

in the high technological areas. One of the most important type of the borate is the lithium borate that has been synthesized in a powder form [3], which resulted from the homogenizing a mixture of the stoichiometric quantities of reactants [Li2CO3and H3BO3] at 750 oC for 14 hrs. Lithium borate namely lithium tretraborate and lithium triborate produced by different methods to be used as [TL] dosimetry [4, 5]. Initially lithium borate is a white powder which has a indistinctive order, and it has a melting point of 917 oC and solubility is in a moderate range of [1-10%] along with a density of 2.4 g/cm3[4]. Lithium borate possesses numerous technological piezoelectricity [pressure induced electricity] [6]. Borate glasses are very interesting amorphous materials considering their specific structure and physical properties, lithium borate is rather new in TL dosimetry compared to lithium tetraborate [7, 8]. Thermoluminescent [TL] dosimetry is an important technology utilized to measure the radiation exposure of this synthetic borate [9, 10]. The technological properties of lithium borate are peculiar crystallization system. In the recent years, thermoluminescent properties of lithium borate [LiB_3O_5] have also attracted many attentions from the scientists and researchers for the medical applications, due to their effective atomic number, which is very close to the biological tissue. In the present study is focused on identifying the physical properties of lithium borate glass that prepared with a different concentrations, then followed by an irradiation process to come out by analysis the glow curve lithium borate.

Table 1 Different compositions of four sample Boric acid and Lithium Carbonate

Sample / Material	Boric acid H_3BO_3 (mol %)	Lithium Carbonate Li_2CO_3 (mol %)
1	90	10
2	85	15
3	80	20
4	75	25

2.0 EXPERIMENTAL

Glass of different compositions in the system of xLi_2CO_3 and (100-x) H_3BO_3 is shown in Table 1. Figure 1 shows the flow chart of the methodology process. The samples were melted in an alumina crucible at 1100°C for 1 hour in an electrical muffle furnace. The melted glass was poured on the preheated steel block to cool rapidly to the room temperature. The glass samples were annealed at 300°C for 10 hrs to make the electrons that located at shall surface more stabilized and then subsequently cooled slowly inside the furnace until the room temperature to avoid the thermal stress. X-ray powder diffraction studies were performed at the room temperature on the annealed glass samples to confirm their amorphous structure. Subsequently, γ-ray photons (^{60}Co) was used to irradiated the glass samples by applying of 10 Gy. The thermoluminces was used to measure the glow curves of the irradiated glass samples.

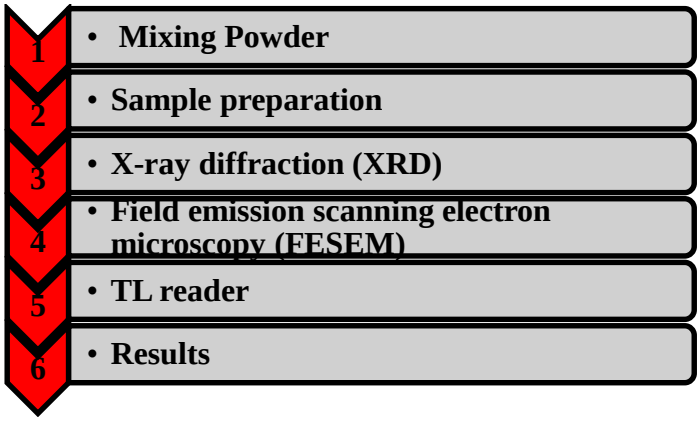


Figure 1 Flow chart of research methodology

3.0 RESULTS AND DISCUSSION

3.1 FESEM and XRD Analysis

The field emission scanning electron microscope (FE-SEM) appraoch was done for the four different glass samples characterized by the XRD, as shown in Figure 2. The data measured to identify the material theme of the glass material and as easily to notice traces of contaminated material that can move the glass

samples. The results revealed that prepared glass have an amorphous structure.

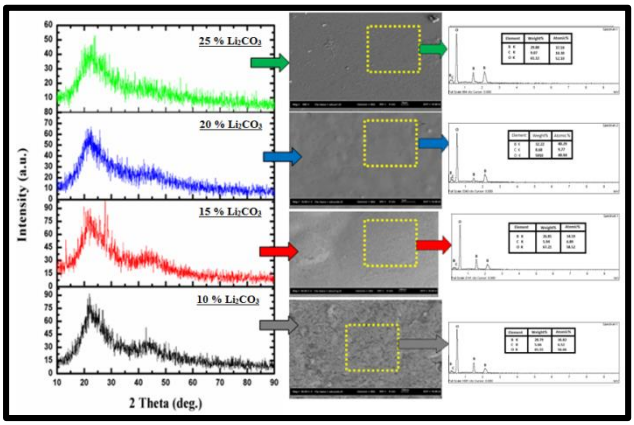


Figure 2 FESEM, XRD, and EDX of the prepared glass samples

3.2 The Glow Curve

The glow curves are particularly important since they are the main indicators of whether a material can be used for the TL dosimetry purpose. It is desired that the glow curve gives a simple, if possible single peak, at around 200°C the peak observed at low temperature in the proximity of 100°C fade away quickly hence they do not yield any information about the radiation content. Generally, this maximum is not symmetric and the half-width of this peak is a wide, these properties of shoulder peak imply that it has a complicated nature. Such maximum is claimed to root from the superposition of a number of local trapping at a certain level [4] in a similar way peaks observed around 300°C are not assigned to good TL properties. Another custom to be followed is performing the readings after 24 hours from the irradiation process [4], the glow curve recorded for lithium borate showed that for [15%Li_2CO_3 + 85% H_3BO_3] sample, the major peak was at 94.10 nc as indicated in Figure 3, which it is a presented a significant property considering the radiation dosimetry potential that lithium borate has one thermoluminescence peak of 94.10 nc. Based on these results the best compositions for these glasses (LiB_3O_5) are those with [15%Li_2CO_3 + 85% H_3BO_3].

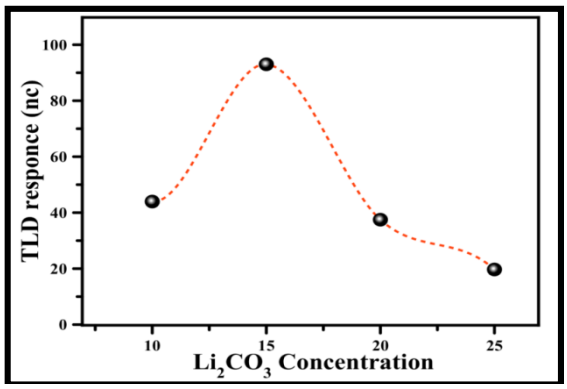


Figure 3 TLD responses versus Li2Co3 concentration of the prepared glass samples

3.3 Sensitivity

The sensitivity of a TL material is another important characteristic of dosimetry material. The TL sensitivity is expressed as glow curve area per unit mass of dosimeter and per unit dose (nC g-1 Gy-1). The TL sensitivity can be calculated as $(\text{sensitivity} = \frac{\text{nc/m}}{\text{dose}})$, and the results were plotted in Figure 4. It was found that the highest sensitivity was indicated with the composition of [15%Li2CO3 + 85% H3BO3], which was about 138.306 nC g-1 Gy-1.

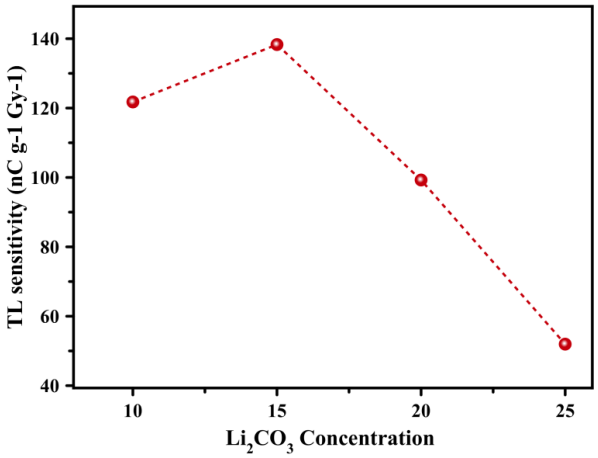


Figure 4 TL sensitivity versus Li2Co3 concentration of the prepared glass samples

4.0 CONCLUSION

The present experiment has been made towards a systematic steady on TL and glow curve investigated of lithium borate material. TL have been recorded for all glass materials and found at the (15% Li_2CO_3 + 85% H_3BO_3) it's have highest TLD responses among the compositions. The amorphous nature of prepared glass material was confirmed by XRD diffraction and FESEM. Hence it is suggested that these glass materials are useful for the future doping.

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References

[1] Ehrt, D. 2000. Structure, Properties and Applications of Borate Glasses. *Glass Technology-European Journal of Glass Science and Technology Part A*. 41: 182-5.

[2] Wang, S., Alekseev, E. V., Stritzinger, J. T., Depmeier, W., Albrecht-Schmitt, T. E. 2010. Crystal Chemistry of the Potassium and Rubidium Uranyl Borate Families Derived from Boric Acid Fluxes. *Inorganic Chemistry*. 49: 6690-6.

[3] Griscom, D., Taylor, P., Ware, D., Bray, P. ESR. 1968. Studies of Lithium Borate Glasses and Compounds γ Irradiated at 77° K: Evidence for a New Interpretation of the Trapped- Hole Centers Associated with Boron. *The Journal of Chemical Physics*. 48: 5158-73.

[4] Pekpak, E., Yilmaz, A., Özbayoglu, G. 2010. An Overview on Preparation and TL Characterization of Lithium Borates for Dosimetric Use. *Open Mineral Processing Journal*. 3: 14-24.

[5] Kar, S., Verma, S., Bartwal, K. 2008. Optical Inhomogeneities in Li2B4O7 Single Crystals. *Crystal Research and Technology*. 43: 438-42.

[6] Damjanovic, D. 1998. Materials for High Temperature Piezoelectric Transducers. *Current Opinion in Solid State and Materials Science*. 3: 469-73.

[7] Radu, A., Borodi, G., Stefan, R., Biris, A., Baia, L. 2014. Highlighting of Structural Units of B2O3–Li2O–P2O5 system Under Heat Treatment. *Materials Chemistry and Physics*. 143: 1271-7.

[8] Graham, J. J. 2014. Hydrothermal Crystal Growth of Lithium Tetraborate and Lithium Gamma-Metaborate. DTIC Document.

[9] Azorin, J., Furetta, C., Scacco, A. 1993. Preparation and Properties of Thermoluminescent Materials. *Physica Status Solidi (a)*.138: 9-46.

[10] keya, M. 1993. New Applications of Electron Spin Resonance: Dating, Dosimetry and Microscopy: World Scientific.